RESEARCH DEPARTMENT

CRYSTAL PALACE BAND V FIELD STRENGTH SURVEY

Report No. K-141

(1959/25)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

CRYSTAL PALACE BAND V FIELD STRENGTH SURVEY

Report No. K-141

(1959/25)

ABHowe

R.S. Sandell (A.B. Howe)

This Report is the property of the British Broadcasting Corporation and may not be reproduced in any form without the written permission of the Corporation.

Report No. K-141

CRYSTAL PALACE BAND V FIELD STRENGTH SURVEY

Section	Title	Page
	SUMMARY	1
1	INTRODUCTION	1
2	GENERAL	3
	2.1. Transmitters	3
	2.2. Receiving Equipment	3
3	METHOD OF MEASUREMENT AND ANALYSIS	4
4	RESULTS	12
	4.1. Survey Maps	12
	4.2. List of Towns Surveyed	21
	4.3. Other Results	24
5	CONCLUSIONS	25
6	REFERENCES	26
	APPENDIX	27

December 1959

Report No. K-141

(1959/25)

CRYSTAL PALACE BAND V FIELD STRENGTH SURVEY

SUMMARY

This report describes the results obtained from a field strength survey of a Band V high-power experimental transmitter installed at Crystal Palace. The work was part of a comprehensive schedule of tests undertaken by several organizations to assess the potentialities of the u.h.f. band for television broadcasting. Measurements and observations for the field strength survey were made by units of the D.S.I.R. Radio Research Station, the G.P.O., the I.T.A., and the B.B.C. Research Department.

Two principal contour maps have been produced, one as measured for an effective radiated power (e.r.p.) of 125 kW, and one for a possible e.r.p. of 1000 kW. A list of the field strength values obtained in the larger towns is also shown, together with comparable figures of the service at present provided by the Crystal Palace Band I transmitter. Using information gained from picture appraisal tests, other maps have been issued[1] showing the areas in which a satisfactory service is available to stated proportions of the population.

The technique of measurement adopted by the B.B.C. is discussed in some detail since there have been fundamental changes as a result of experience gained from previous u.h.f. and v.h.f. methods.

Work which involved picture monitoring has not been described here, as this came within the scope of separate teams primarily concerned with picture assessment.

1. INTRODUCTION

Long distance propagation tests, using Band IV frequencies, were started by the B.B.C. in 1955. These tests have continued over a long period, using transmitters installed at Pontop Pike, Holme Moss and Sutton Coldfield, field strengths of these transmissions being recorded at various unattended sites at prescribed distances.

In 1956 the first field strength survey of a u.h.f. transmitter in this country was made using a low-power transmitter operating on 495 Mc/s and sited at Crystal Palace. Using a directional transmitting aerial mounted at 430 ft (131 m) above ground level on the permanent mast the whole of the area was surveyed and the results provided a forecast of the extent of the service area of a high-power u.h.f. transmitter. Square-wave modulation was employed for normal field strength measurement, and pulse modulation for multipath interference investigations. The results of this survey have been described in the final report of the Crystal Palace Band IV survey[2].

In the same year the Technical Sub-Committee of the Television Advisory Committee considered that full assessment of the potentialities of u.h.f. could only be gained through picture transmissions. Also, it was felt desirable that the Western European 625-line system should be compared with the present British 405-line system at u.h.f.

The B.B.C. subsequently installed a high-power u.h.f. transmitter and associated helical aerial at Crystal Palace in order to carry out a series of test transmissions. These transmissions were divided into two distinct parts (Series A and Series B). In Series A the standard British 405-line system was used and in Series B tests were made using the Western European 625-line system.

Several interested organizations equipped mobile laboratories, staffed by technical personnel, for assessment of the pictures, and in addition a large number of specially produced commercial receivers was distributed for home viewing by both technical and non-technical viewers. Comparisons were made between Band I and Band V pictures, and the subjective assessments were recorded on special forms which were subsequently submitted to statistical analysis.

Although the mobile laboratories taking part in these tests made field strength measurements for correlation with their picture assessments, these were necessarily limited in number by the time available, and alone they would not have been sufficient to provide the requisite data for the service area survey maps. A separate field strength survey was therefore made by field strength measurement units not normally concerned with the vision tests. Measurements by these units were, in general, made at a receiving aerial height of 30 ft (9·1 m) above ground level.

Methods of measurement at v.h.f. employ the "continuous" technique whereby a continuous record of field strength is made by a travelling vehicle with a suitable chart recorder geared to the road wheels. In this technique the receiving aerial is mounted at a low height on the vehicle and a linear height-gain correction factor is added to the results to derive the field existing at 30 ft (9·1 m) above ground level. Although this method is suitable for use at v.h.f. the absence of a constant height-gain factor at u.h.f. has precluded this technique at the higher frequencies. However, measurements were also made at lower aerial heights and sufficient information is now available to investigate the possibility of a return to the continuous method of measurement.

The measuring techniques adopted by each of the field strength units were fundamentally different, although precautions were taken to ensure that actual field strength measurement produced the same absolute results. This was achieved by the calibration of all the field strength measuring sets, using facilities provided by the D.S.I.R. Radio Research Station at Slough. Since the B.B.C. completed the survey of the whole area using their own methods the maps and results are based upon B.B.C. measurements, although supplementary information supplied by other organizations has enabled some of the results to be checked.

2. GENERAL

2.1. Transmitters

The transmitters installed at the permanent Band I station at Crystal Palace for the purposes of the u.h.f. tests were a 10 kW peak-white u.h.f. vision transmitter and a 2·5 kW carrier sound transmitter. For the Series A tests the vision transmitter operated on a frequency of 654·25 Mc/s and used the normal standard television waveform on 405 lines. The sound transmitter used a frequency of 650·75 Mc/s and was amplitude modulated. For the Series B tests, using the 625-line standards, negative modulation was employed for the vision transmitter. The sound frequency was raised above the vision carrier to 659·75 Mc/s, and was frequency-modulated with a deviation of ± 50 kc/s.

The transmitter outputs were fed through waveguide feeders to a helical aerial mounted on the permanent self-supporting mast. The mid-point of the aerial was 691 ft (211 m) above ground level, and the e.r.p. of the vision transmitter was 125 kW. The aerial had a sharply defined lobe in the vertical field which affected an area within 14 miles (22 km) of the transmitter. It was not practicable to apply corrections to all the results obtained within this area to compensate for the irregularities in the vertical radiation pattern, but corrections were applied for the more general effects due to the horizontal radiation pattern. Static recordings were made at two receiving sites in order to check the output of the sound transmitter, which was subject to slight fluctuations in radiated power. The use made of this facility has demonstrated the need for similar precautions in future survey work. It is necessary, of course, to ensure that field strength variation at the receiving site is due to a change in transmitter e.r.p. and not to varying obstructions in the transmission path.

2.2. Receiving Equipment

The receiving aerial used by the B.B.C. unit was a three-element Yagi fitted with a screen giving a front/back ratio of approximately 30 dB. High directivity was obtained with this aerial, the half-power points appearing at ± 15°. The measuring vehicle was equipped with a pneumatically-operated mast capable of elevating the aerial to heights up to 35 ft (11 m) above ground level. The compressor for this mast was driven from the vehicle engine, and the aerial could be raised to the measuring height of 30 ft (9·1 m) in 40 seconds.

The receiver was developed from earlier models used extensively for measurement at u.h.f. and v.h.f. The r.f. unit incorporated a modified R.C.A. tuner and facilities were provided to switch the input, via a directional coupler, to the output of a built-in calibration oscillator, in order to check the receiver gain. The input to the 30 Mc/s i.f. unit was controlled by a variable attenuator, and the i.f. unit itself contained the linearity and gain controls. The output was displayed on a 0-1 mA meter and a recording milliammeter was also used. For normal survey measurement the output was adjusted to give a logarithmic response and the signal was read directly from the scale of the milliammeter, the result being added to any attenuation introduced before the i.f. unit. R.F. inputs down to 10 dB above a microvolt (open circuit) could be measured and this covered normal requirements.

Power for the vehicle equipment was provided by a small petrol-driven generator with a rated output of 800 VA.

Before starting the tests, and at intervals thereafter, facilities were provided by the D.S.I.R. Radio Research Station at Slough for checking the accuracy of the individual receiver and aerial calibrations.

3. METHOD OF MEASUREMENT AND ANALYSIS

Broadly, the requirements of a field strength survey of an existing v.h.f. or u.h.f. transmitter are as follows:

(i) Measurements of the overall service area down to the minimum acceptable field strength in terms of the actual or projected e.r.p. of the transmitter.

(ii) Detailed measurements in built-up areas within the service area so that the strength of signal available to stated proportions of the population may be known.

(iii) The investigation and assessment of various propagation characteristics, such as fading, multipath interference, aircraft flutter, and others. Observation of many of these is facilitated by visual displays which may indeed be essential. In the Band V tests these characteristics were generally assessed by the mobile laboratory teams undertaking the picture quality tests.

In order to fulfil requirements (i) and (ii) above, it is essential that the compilation of field strength results should be made from as many measurements as possible. The number of measurements possible is limited primarily by the time factor, and since the majority of viewers live in towns and large villages most of the time was used to make measurements in such localities. Sufficient information is obtained from these results to define the service area.

It has already been mentioned that each organization used a method of field strength measurement which they found gave satisfactory results and which was best suited to the facilities available to them. This report describes the technique used by the B.B.C. and its development through experience gained on Band V as well as, over many years, on the v.h.f. bands. One feature common to all the field strength units taking part in this work is the absence of a sufficiently accurate height-gain correction factor, to enable measurements, made at a low receiving aerial height, to be corrected for the "standard receiving aerial height" of 30 ft (9·1 m) above ground. This has meant that the actual measurements during the tests had to be made at a receiving aerial height of 30 ft (9·1 m) above ground level, thus slowing down the survey and limiting the number of measurements available in a given time.

Earlier u.h.f. measurements in Band IV from Crystal Palace[2] had already shown that the standard method of continuous measurement and the use of the proportional height-gain factor, as used in the v.h.f. bands, were not sufficiently valid for accurate results. In rural open areas within optical range of the transmitter the median height-gain factor was generally less than expected, while in built-up areas the reverse was true, due to the screening effect of buildings on the aerial at low height, and the increased shadow loss at u.h.f. Deviations from the median height-gain value were wide, particularly at sites where the greatest component of the received signal was provided by diffraction, e.g., in the shadow of buildings and hills. The conclusion was that the use of constant height-gain corrections to town measurements gave very inaccurate results when compared with actual measured values with the receiving aerial at 30 ft (9·1 m) above ground level.

Several other procedures were considered, including:

(a) Spot measurements or short cruises with the receiving aerial at 30 ft (9·1 m) above ground level;

(b) Spot measurements on roofs, (not practicable when applied to large areas);

(c) Continuous measurements with the aerial 30 ft (9·1 m) above ground level; and

(d) Continuous cruises with the receiving aerial at 12 ft (3·7 m) above ground level using a revised method of conversion to the 30 ft (9·1 m) value.

It will be appreciated that the practical difficulties of mobile measurement with the receiving aerial elevated to 30 ft (9·1 m) are severe, and so investigations were concentrated on method (d). It was found that ratios between measurements at aerial heights of 12 ft (3·7 m) and 30 ft (9·1 m) showed minimum scatter when only those parts of the lower aerial record, which were measured when the receiving aerial was clear of local obstructions, were considered. The addition of a constant height-gain factor obtained from open-country experiments to these values gave a reasonably accurate assessment of the field strength as measured at 30 ft (9·1 m) above ground level. As a result of a large number of height gains in open country a mean figure of 5 dB was adopted for the constant height-gain factor. Full details of this system and work dealing with it are contained in the final report of the Crystal Palace Band IV survey[2].

At the time it was realised that there were certain shortcomings in this procedure but these were accepted since a better method was not forthcoming. The greatest difficulty was that of deciding when the terrain was, in fact, open in the direction of the transmitter from the moving measuring vehicle, and the instantaneous transfer of this information to the recorder chart. This rapid estimation of prevailing receiving conditions introduces a source of error into the analysis. It was felt that this subjective appraisal might produce a result unique to the operator, and that subsequent surveys by different operators would produce different values.

More recent studies have shown that the widespread use of an omnidirectional receiving aerial for mobile measuring purposes at u.h.f. can give rise to further discrepancies. This was revealed when Band IV measurements were being analysed for information concerning local variation factors. More complete details concerning variation factors are contained in Section 4.2 of this report, but it is sufficient at this stage to state that the variation factor of any small area is the difference between the field strength values at 50% and 90% of the locations. If the area considered is sufficiently small, so that terrain changes may be discounted, the differences will be due to local obstacles such as buildings and trees.

If the theoretical factors are considered, the field strength at any point near the surface of the earth is the vector sum of the fields due to the direct ray and to that reflected from the ground. It is evident that in practice the reflected ray will consist of several components from different reflecting surfaces, but in the ideal condition the two principal rays alone are considered. Then the field strength E is given by

$$E = \frac{88\sqrt{P}\,h_T\,h_R}{\lambda d^2} \text{ volts/metre}$$

where P is in watts
and h_T, h_R, λ and d are in metres.

Thus, since wavelength λ is inversely proportional to frequency the field strength is directly proportional to frequency, other parameters remaining constant. From this it may be expected that measurements at open sites within optical range of the transmitter will show evidence of what is sometimes called "frequency gain". (The optical range of Crystal Palace Band V aerial is approximately 37 miles (60 km).)

The effect of the interference caused to optical rays by the obstruction of a straight edge is well known to physicists from the classic work of Fresnel some 140 years ago. In the case with which we have to deal, the ratio of the amplitude of the obstructed wave to the unobstructed is approximately inversely proportional to a parameter v, where

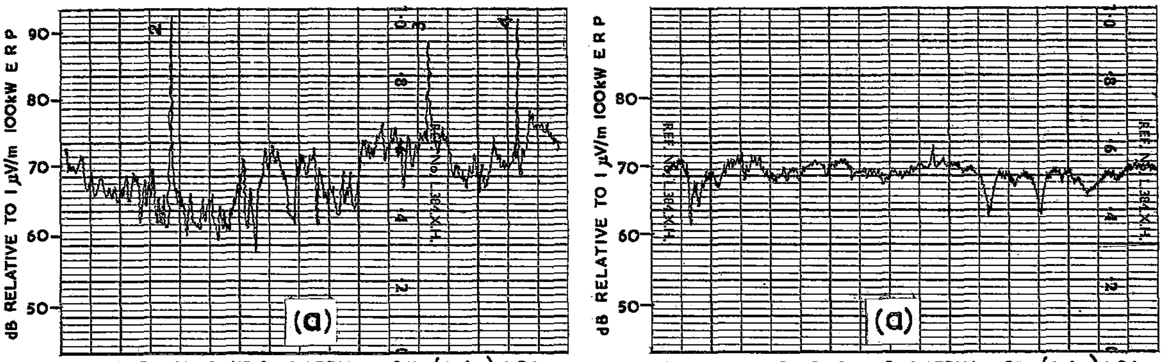
$$v = s\sqrt{\frac{2d}{d_1\,d_2\,\lambda}}$$

where s = height of obstacle
d = distance between transmitter and receiver
d_1 = distance between transmitter and obstacle
d_2 = distance between obstacle and receiver.

Thus v is proportional to $\sqrt{f}$, and the ratio of the shadow loss at two frequencies is inversely proportional to the square root of the frequency ratio. If the Band V frequency of 650 Mc/s is compared with the Band I 45 Mc/s transmission it follows that the u.h.f. signal will be reduced by a further attenuation of 11·6 dB in regions of deep shadow. Thus the effect of obstacles in an arbitrarily selected propagation path of the higher frequency may introduce attenuation between 0 and 11·6 dB.

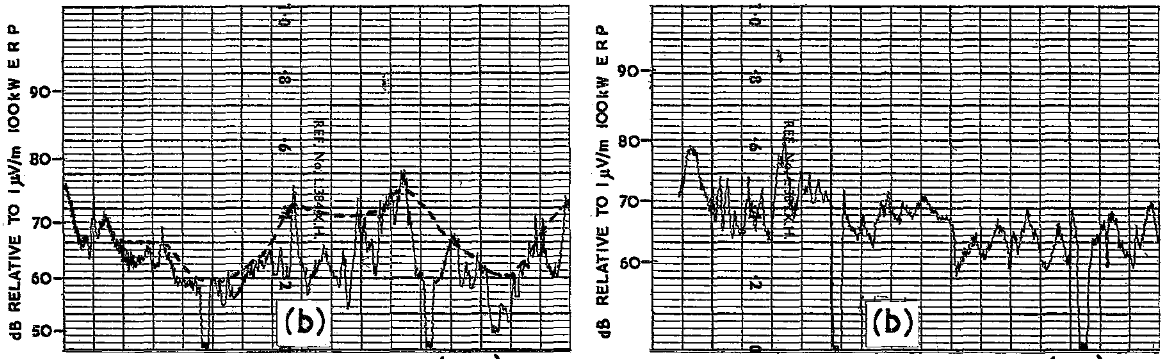
From the simple theoretical considerations briefly outlined here it is reasonable to expect the variation factor to increase with frequency. In fact, however, Band IV measurements made with an omnidirectional receiving aerial failed to show this. This was attributed to the involuntary measurement of indirect reflections when the direct ray was obscured by an obstruction. This effect was particularly noticeable in the analysis of measurements made in towns screened from the transmitter by neighbouring hills. In these cases the inclusion of the measurement of reflections produced an "optimistic" result.

On Band V, initial continuous measurements were made using a directional aerial mounted on the measuring vehicle at 12 ft (3·7 m) above ground level. The aerial was automatically directed towards the transmitter by a gyro-compass and associated servo-mechanism. Use of this selective aerial revealed the true behaviour of the direct signal. Examples of typical recorder charts are shown in Figs. 1 and 2. Fig. 1 shows the charts of Bands I, IV and V for continuous measurements through



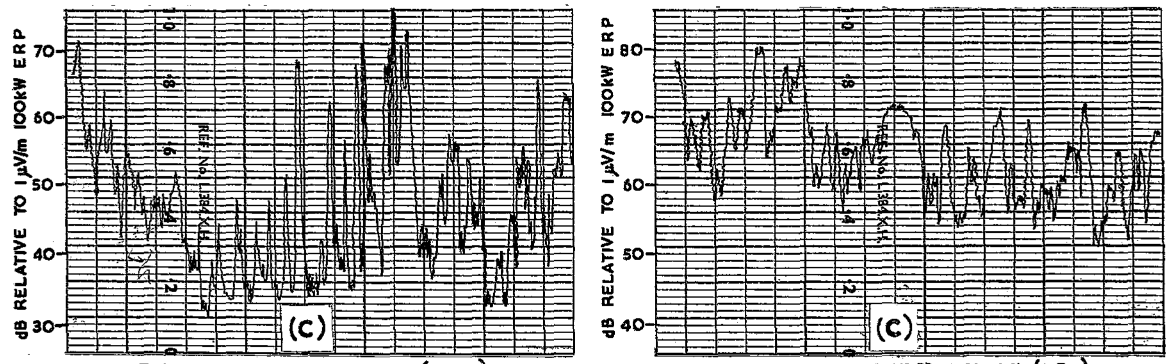
WESTERHAM, BAND I J AERIAL 15ft (4·6m) A G L

TREE-LINED ROAD, BAND I J AERIAL 15ft (4·6m) A G L



WESTERHAM, BAND IV BATWING 12ft (3·7m) A G L

TREE-LINED ROAD, BAND IV BATWING 12ft (3·7m) A G L



WESTERHAM. BAND V YAGI 12ft (3·7m) A G L

TREE-LINED ROAD. BAND V YAGI 12ft (3·7m) A G L

Figs. 1 and 2 - Examples of continuous measurements on Bands I, IV and V using different types of receiving aerial
Each chart shows measurements made over one mile

Westerham, Kent. It will be seen that whereas the difference in signal variation in Band I (Fig. 1(a)) and Band IV (Fig. 1(b)) is barely significant for an increase of eleven times in frequency, the chart for Band V (Fig. 1(c)) reveals much greater variations in signal strength. As stated in the previous paragraph, the measurements on Band IV have given an erroneous impression of the shadow loss at the higher frequencies because of the use of an omnidirectional aerial.

The broken line of the Band IV chart is the line sketched in by the operator during measurement. It connects those parts of the chart he considers to have been recorded whilst the receiving aerial was clear of local obstructions. Because of the enclosing nature of this line the method was known as the "envelope" system. Fig. 2 shows sections of chart recorded on the same frequencies as those relating to Fig. 1, on a tree-lined road in flat, open country. Once again the variation is greater on Band V (Fig. 2(c)) than on Band IV (Fig. 2(b)), although the difference between Band I (Fig. 2(a)) and Band IV is more marked than in the Fig. 1 example, because of the more open nature of the ground and the consequent scarcity of high-amplitude reflections. In both figures the drop-out periods on the Band IV charts are due to transmitter markers. It will be appreciated that, although each chart has been scaled for 100 kW e.r.p., exact comparison of field strengths is inadmissible, since transmitting aerial heights are different, the Band V aerial being 261 ft (80 m) higher than the other aerials. It is doubtful if the similarity in variation between Bands I and IV signals can be attributed to this, since their transmitting aerials are approximately equal in height above ground.

Attempts to "employ" the envelope system of analysis on charts such as that shown in Fig. 1(c) proved difficult in practice. The complication of rapid signal fluctuation made the already complex operation of measurement practically unworkable. Furthermore, comparison between town measurements made with the aerial at 30 ft (9·1 m) above ground level and those made at 12 ft (3·7 m) above ground level with subsequent envelope corrections for 30 ft (9·1 m) values showed little correlation. It was found that although height gains in open country yielded a median figure of 5 dB, those at open sites in towns gave a higher figure, with very wide deviation between individual values. Fig. 3 illustrates the range of height gains in two towns — Crawley and Horsham. These height gains are derived from the comparison of recorded signal over sections approximately 100 yd (91 m) in length at aerial heights of 12 ft (3·7 m) and 30 ft (9·1 m) above ground level. These comparisons were made at randomly chosen sites, although height gains made in situations where the aerial at 12 ft (3·7 m) is in shadow but when elevated is clear produced much higher figures than height gains at open sites, due to the intense shadow loss at u.h.f. Fig. 4 shows the median height gains obtained from measurements in thirty towns in Essex. Although there are wide variations from the median value in many individual towns (illustrated by Fig. 3), most of the median values so far obtained lie between 5 dB and 15 dB. It is evident, from these wide variations, that the addition of a constant height-gain factor to measurements obtained with the receiving aerial at an aerial height of 12 ft (3·7 m) above ground level may give rise to considerable error. Fig. 4 also shows the height-gain curve for measurements in the open country; these confirm the median figure of 5 dB obtained during the Band IV survey.

As a result of these studies it was decided that if the field strength at 30 ft (9·1 m) above ground level was to be stated with reasonable accuracy, measurements would have to be made at that height. The possibility of the development of a technique whereby continuous measurements could be used was nevertheless not excluded,

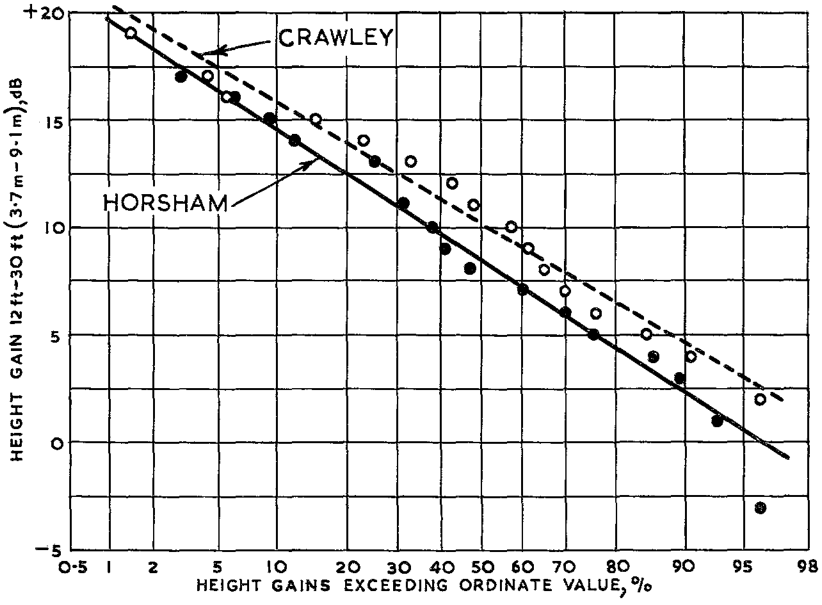


Fig. 3 - Band V height gains in Horsham and Crawley using Yagi aerial at 12 ft and 30 ft (3·7 and 9·1 m) a.g.l., derived from continuous measurements each approximately 100 yards (91 m) in length

Number of sections in Crawley = 83 Number of sections in Horsham = 31

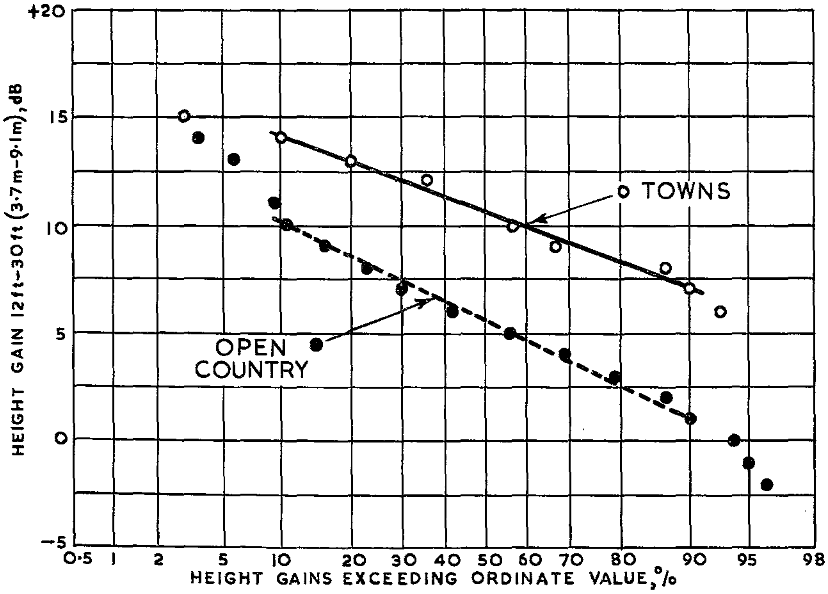


Fig. 4 - Band V height gains using Yagi aerial at 12 ft and 30 ft (3·7 m and 9·1 m) a.g.l., derived from spot measurements in towns and continuous cruises of approximately 100 yards (91 m) in length in the country

Number of town height gains = 900 approx. Number of country height gains = 220 approx.

and investigations to that end have continued. Alternatively, field strength at some agreed lower height could be made, so that continuous measurements could be made at that height without the addition of a height-gain constant, but the usefulness of such information is doubtful.

Short cruises with the aerial elevated to 30 ft (9•1 m) above ground level were found to be possible, provided extremely low road speeds were observed. Unfortunately it was found that, with this procedure, nearly half of the time was devoted to searching for suitable flat, open stretches of road. As a result of this, spot measurements were then considered. While it is difficult to find a sufficient number of open stretches of road in towns it is fairly simple to make a stationary measurement. It was decided to treat the results on a statistical basis by sampling the field strength at a number of different locations in each built-up area, the density of the points being determined by the population density and the number of measurements made being governed by the variation between the maximum and minimum values. Apart from the choice of location the method does not involve any subjective estimation by the operator.

For 95% probability the accuracy of the median is given by[3]

$$\pm \frac{2{\cdot}5\sigma}{\sqrt{n}}$$

where σ = standard deviation of the samples

n = number of samples taken.

This is based on the assumption that the absolute range of variation between maximum and minimum values is 6σ.

An accuracy of ± 2dB was regarded as reasonable, and the number of samples necessary for a given degree of variation is shown in Fig. 5. From this it will be seen that in an area of large field strength variation correspondingly more measure-

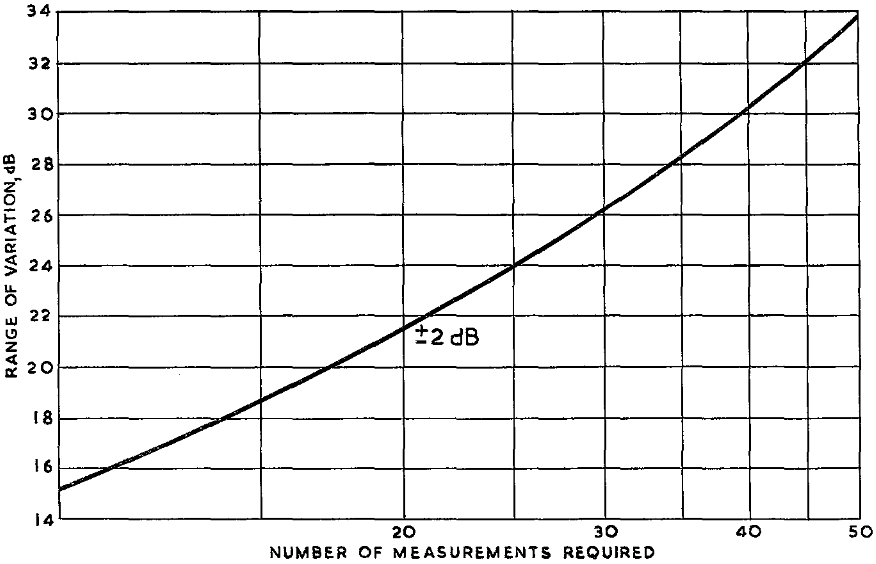


Fig. 5 - Accuracy of median for 95% probability based on the assumption that

$$\sigma = \frac{\text{range of variation}}{6}$$

ments must be made than in areas where variation is small. On this basis the average number of measurements in towns was 45, and in villages 15. In some hilly towns the number of samples necessary to give a median value with the stated accuracy approached 200. At first, in planning the surveys, towns were split up into areas of approximately one square kilometre, but it was found that this involved some unnecessary work, since the median value derived from the town treated as a whole closely approximated to the median value obtained from the medians of its constituent parts. Further, it was easier to weight the density of the samples with regard to population when considering the town as a whole. It is emphasized that the measurements were made in reasonably selected situations corresponding with ultimate domestic aerial sites. No attempt was made to include measurements made in the immediate shadow of large buildings such as cinemas and factories, unless houses were similarly situated. In close proximity to such obstacles it was often impossible to measure any direct signal and it was therefore considered that such measurements were not representative of the area. No effort was made to move the aerial once erected, since the statistical analysis takes care of any effects due to local standing waves. At each site the direct signal was measured and recorded (in preference to any indirect reflections), although isolated instances did occur where the indirect signal greatly exceeded the direct. In five towns measurements were made twice to ensure that the same median value could be repeated using a different but still representative distribution of samples, with due regard to the minimum number necessary for the stated accuracy. Confirmation of the median value in each instance fell within the stated accuracy of ±2 dB (with some fluctuation of the 10% and 90% values).

It is obvious that while measurements at 30 ft (9·1 m) above ground level are desirable the extra time involved may be too great to make the method economically feasible, so time factors were compared.

To assess the time taken for spot measurements comparison was made with Band IV continuous measurements made over an arc of 60° to the south of Crystal Palace. In this arc, spot measurements were made in sixty built-up areas giving adequate, though not complete, detail for the contour map. The number of samples per area averaged twenty, so that 1200 measurements were made. It was found that the rate of working produced approximately fifteen points per hour, so that the time involved in actual measurement was eighty hours. The same sector had been surveyed on Band IV using continuous measurements in approximately the same time, although only 47 hours were spent in built-up areas. However, to preserve accuracy in Band V measurements, it would be necessary to investigate height gains in a proportion of the towns if continuous measurements were made, and this would prolong the time by a considerable amount. In general, it was found that three hours was an average figure to derive a reliable height-gain factor for one town.

The comparison drawn in the preceding paragraph does not, however, give a true picture of the time factor since many more villages were measured during the Band IV continuous measurements. Furthermore, the continuous measurements were carried on during transit between built-up areas, so that more detail was available for the Band IV map. In the v.h.f. band the open-country measurements are used extensively to complete the final survey map, although the Band IV map was finally drawn using measurements in built-up areas only. It is very doubtful whether measurements could be made in sufficient detail for a complete map at u.h.f., and it was therefore considered that the best compromise was to survey areas in which the majority of the population lived. With the information derived from these surveys, the map could then be drawn using these measurements with due consideration of the ground contours in intervening country. It may be that a combination of spot measurements in built-up areas with continuous measurements in the country will produce the most satisfactory results in future u.h.f. surveys. The time factor for spot measurements will be increased if the technique is employed in a service area covering more hilly terrain than that found in the Home Counties, since the increased variation in signal strength will make it necessary to increase the number of measurements.

4. RESULTS

4.1. Survey Maps

Figs. 6 and 7 (maps T.451 and T.452) show the service areas for e.r.p.s of 125 kW and 1000 kW respectively. Both of these maps are based upon spot measurements in some 250 towns and villages, together with additional radial measurements in rural areas made by field strength units of the I.T.A. and the G.P.O. For comparison, Fig. 8 (map T.471) illustrates the present service provided by the existing Band I transmitter at Crystal Palace. It is important to realize that, particularly in the Band V maps, the reduced scale has caused much detailed information to be lost, and the intense shadow loss at u.h.f. is not readily apparent from the maps. In the shadow of nearby hills there are sharp decreases in field strength, illustrated to some extent by the proximity of the field strength contour lines to each other along the southern face of the North Downs, and along the northern escarpment of the Chiltern Hills. In order to show this with any clarity it has been necessary to open up the contours at such places, although a steep drop in signal often takes place over a distance of a few yards. A more detailed map gives a clearer indication of the variation and Fig. 9 (map T.468) shows a contour map of High Wycombe drawn from Band V measurements. This is a fairly hilly town, and even on a map of this scale it is not possible to give all the detail revealed by measurement. Fig. 10 (map T.469) shows a similar map drawn from Band I measurements — the decrease in signal variation is immediately apparent. Such conditions exist in all hilly areas, indeed in every hilly town investigated and, except where the hill faced the transmitter, there were areas of poor reception. Many places, such as Purley, Coulsdon, Kenley, Muswell Hill, Hampstead and Hanwell, which are all within 15 miles (24 km) of the transmitter, suffered from severe shadow loss due to hills. It will be evident that, while overall terrain changes affect a large number of receiving sites, the shadows cast by local obstacles, such as gas holders and tall buildings, will make receiving conditions bad in some localities, although the careful siting of the receiving aerial can often bring much improvement.

Information supplied by the subjective assessment of pictures has permitted the "percentage service" maps shown in Figs. 11 and 12 (maps T.454 and T.455) to be drawn up. These show the areas of first-class (95% served) and second-class service (70% served) for 125 kW and 1000 kW e.r.p. respectively. They are based on measurements in built-up areas, taking into account the field strength variations in each town and village. Fig. 13 (map T.461) shows the comparable Band I map, although this also includes the second-class service boundary for rural areas. This rural service is based on the premise that a higher field strength is needed on Band I to ensure a given signal/noise ratio in urban areas than in country districts, where there is less man-made electrical noise. In Band V this distinction is unnecessary since the interference due to such noise is very slight.

T 451

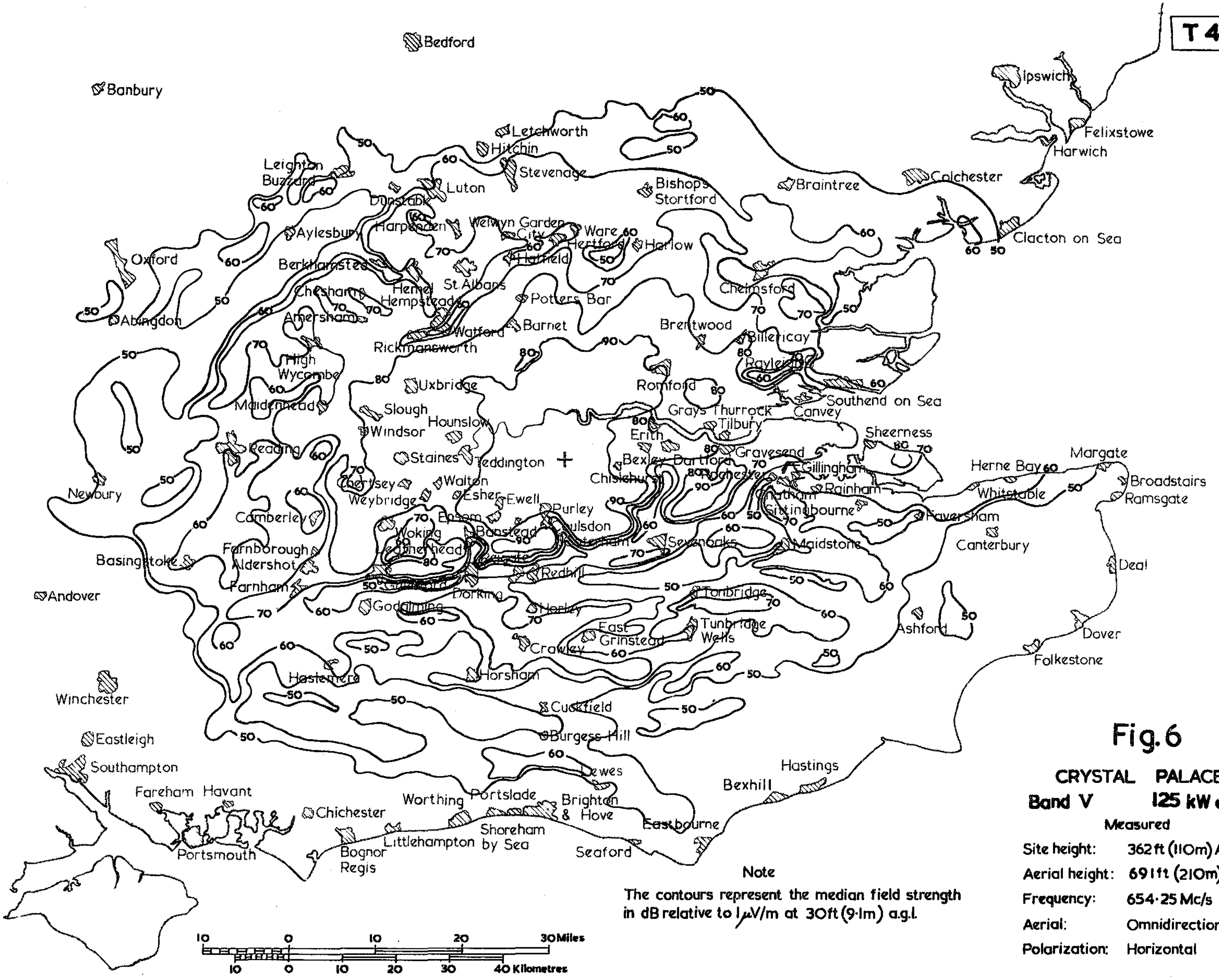


Fig. 6

CRYSTAL PALACE

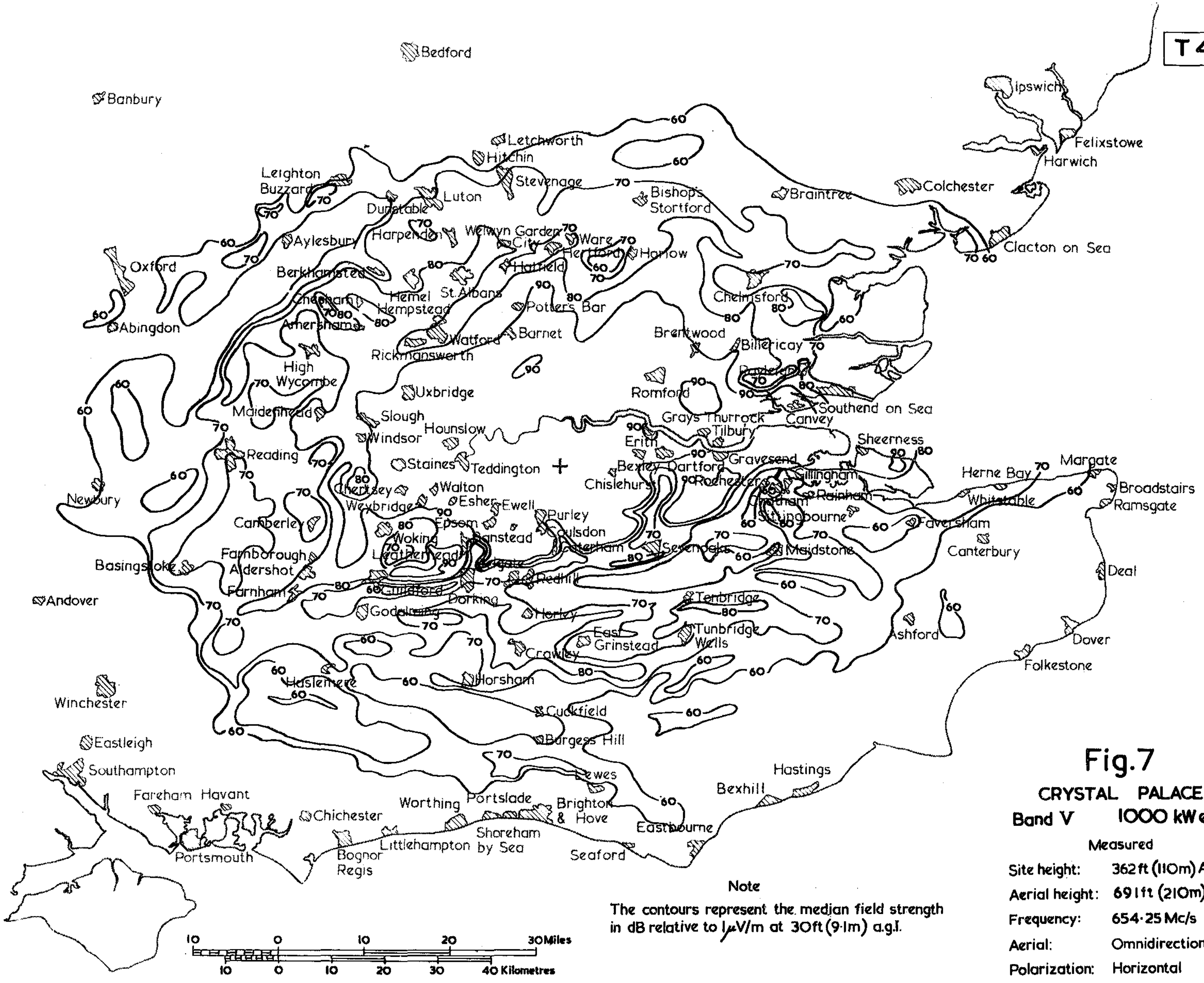
Band V **125 kW e.r.p.**

Measured

Site height:	362 ft (110m) AMSL
Aerial height:	691 ft (210m) AGL
Frequency:	654·25 Mc/s
Aerial:	Omnidirectional
Polarization:	Horizontal

Note

The contours represent the median field strength in dB relative to 1 μV/m at 30ft (9·1m) a.g.l.



Note

The contours represent the median field strength in dB relative to 1μV/m at 30ft (9·1m) a.g.l.

Fig.7

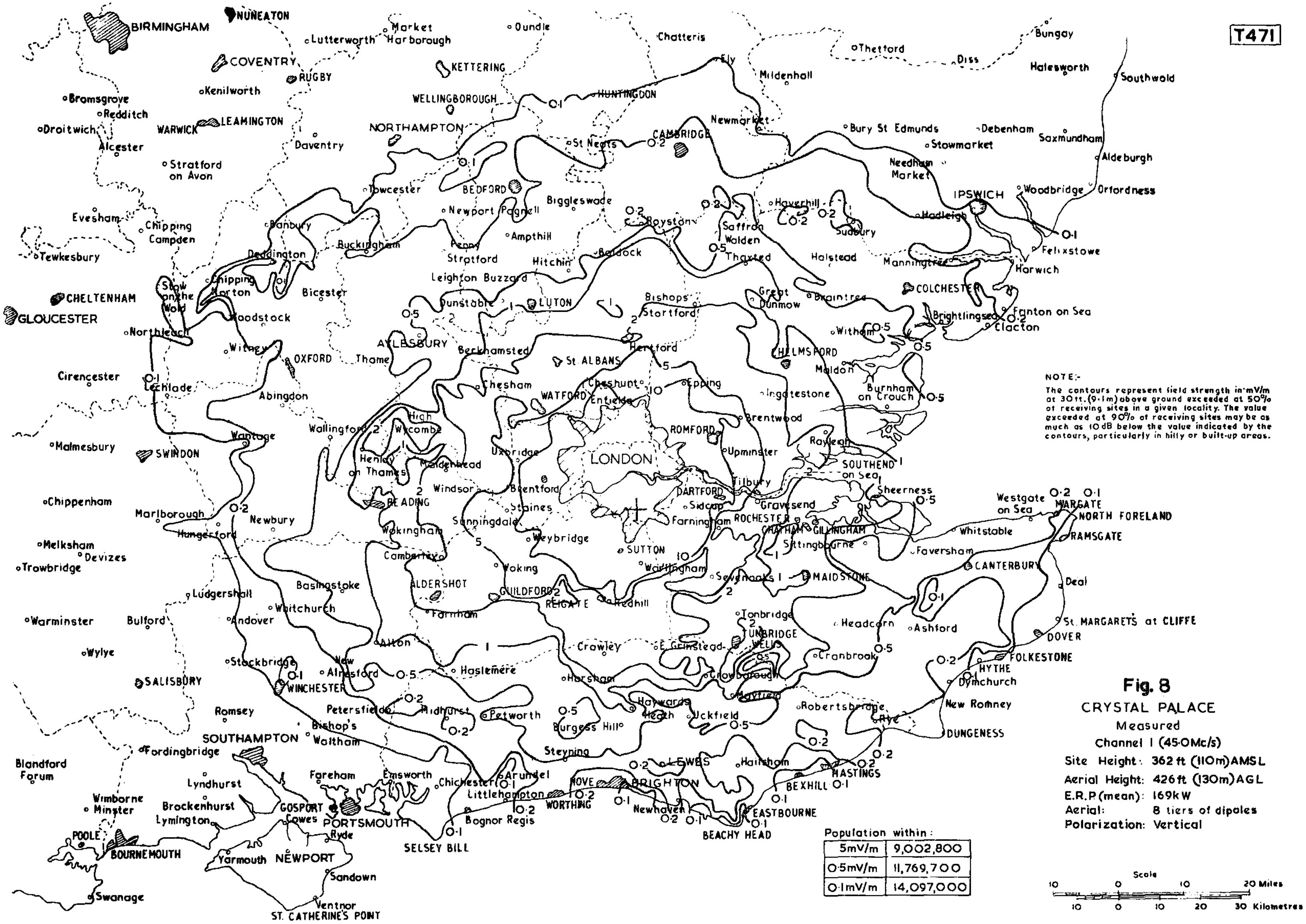
CRYSTAL PALACE

Band V 1000 kW e.r.p.

Measured

Site height:	362 ft (110m) AMSL
Aerial height:	691 ft (210m) AGL
Frequency:	654·25 Mc/s
Aerial:	Omnidirectional
Polarization:	Horizontal

T471



NOTE:- The contours represent field strength in mV/m at 30ft.(9·1m) above ground exceeded at 50% of receiving sites in a given locality. The value exceeded at 90% of receiving sites may be as much as 10 dB below the value indicated by the contours, particularly in hilly or built-up areas.

Fig. 8

CRYSTAL PALACE

Measured

Channel 1 (45·0Mc/s)

Site Height: 362 ft (110m) AMSL

Aerial Height: 426 ft (130m) AGL

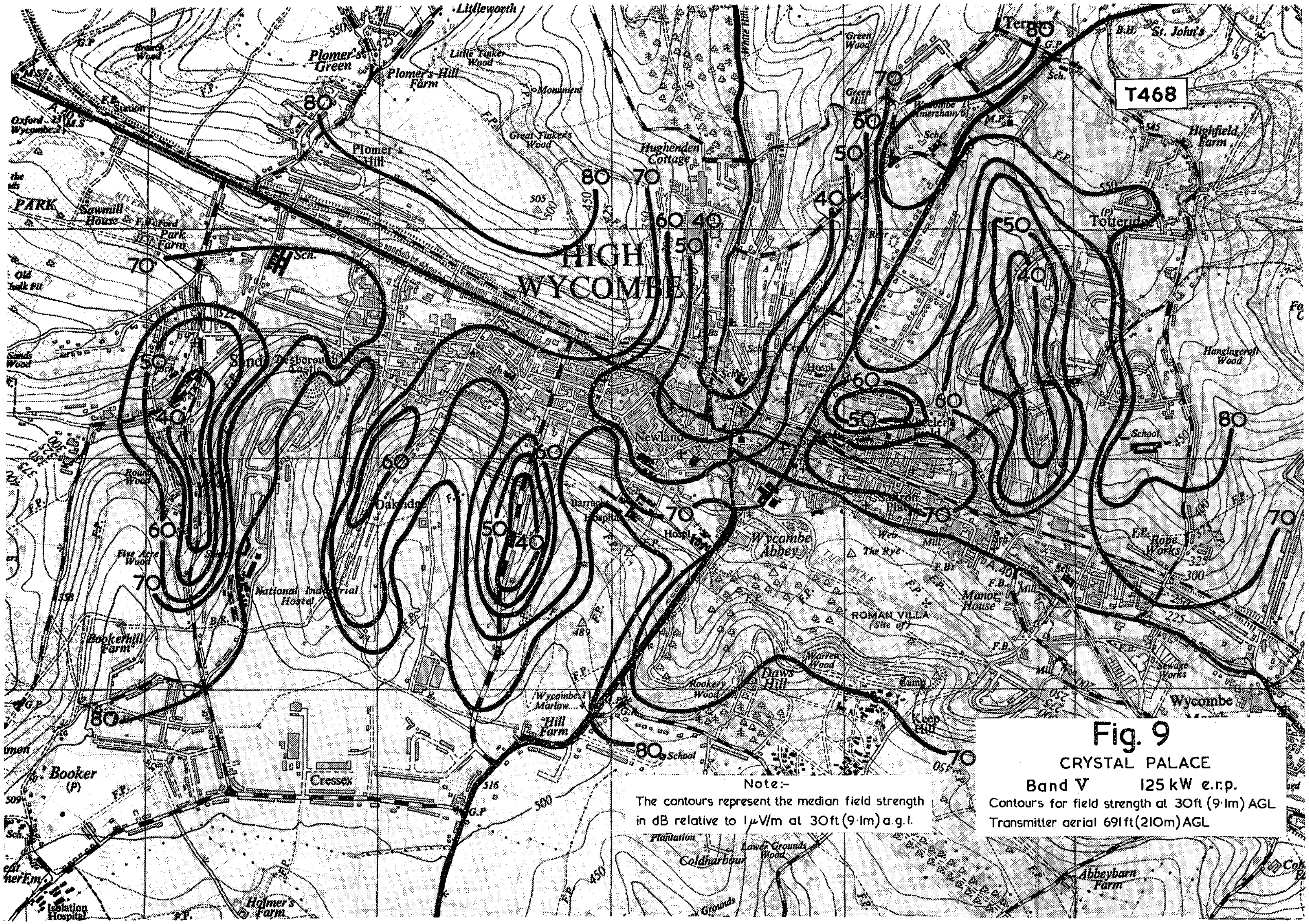
E.R.P (mean): 169kW

Aerial: 8 tiers of dipoles

Polarization: Vertical

Population within:

5mV/m	9,002,800
0·5mV/m	11,769,700
0·1mV/m	14,097,000



Note:-
The contours represent the median field strength in dB relative to 1μV/m at 30ft (9·1m) a.g.l.

Fig. 9
CRYSTAL PALACE
Band V 125 kW e.r.p.
Contours for field strength at 30ft (9·1m) AGL
Transmitter aerial 691ft (210m) AGL

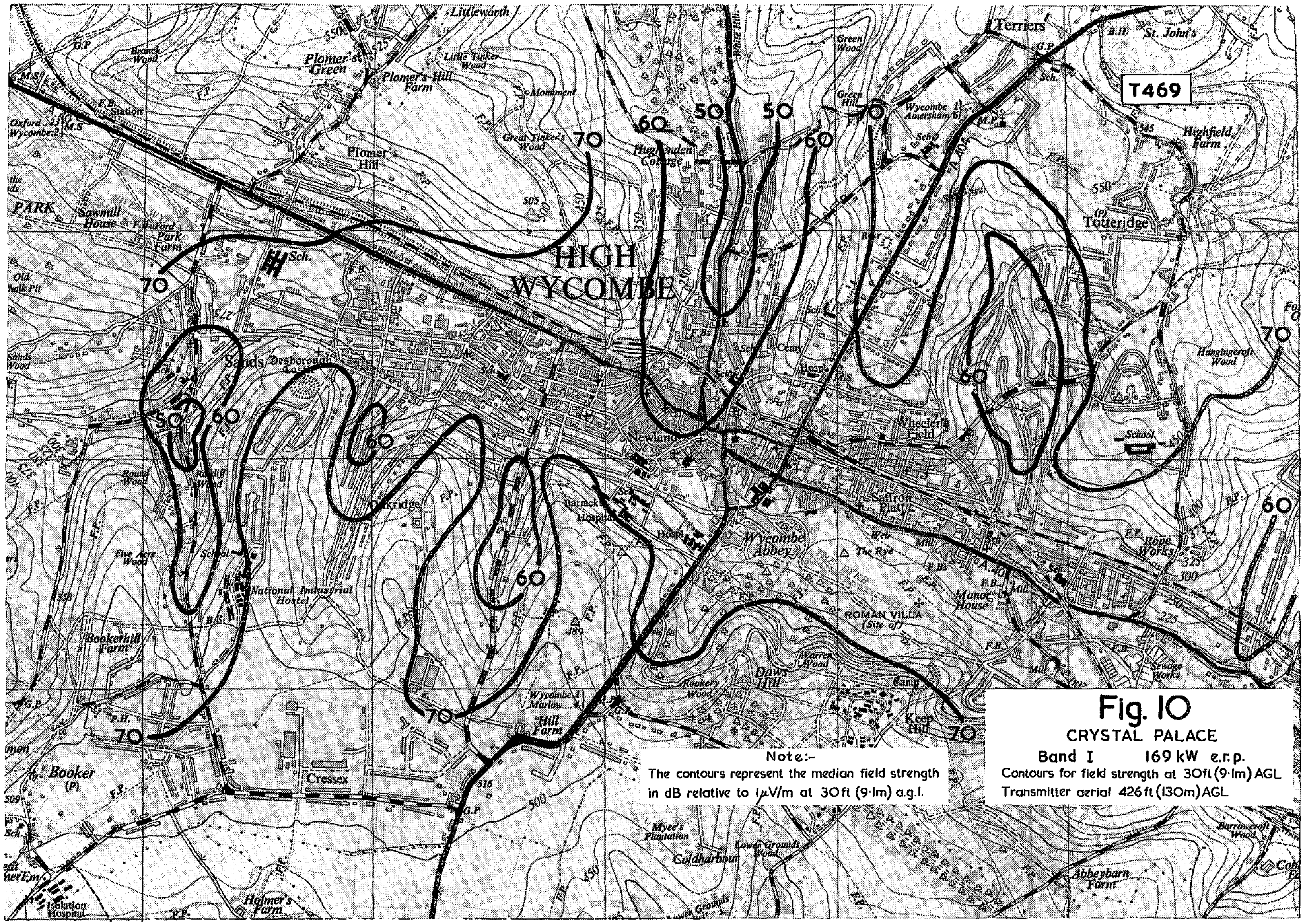


Fig. 10

CRYSTAL PALACE

Band I 169 kW e.r.p.

Contours for field strength at 30ft (9·1m) AGL

Transmitter aerial 426 ft (130m) AGL

Note:-

The contours represent the median field strength in dB relative to 1μV/m at 30 ft (9·1m) a.g.l.

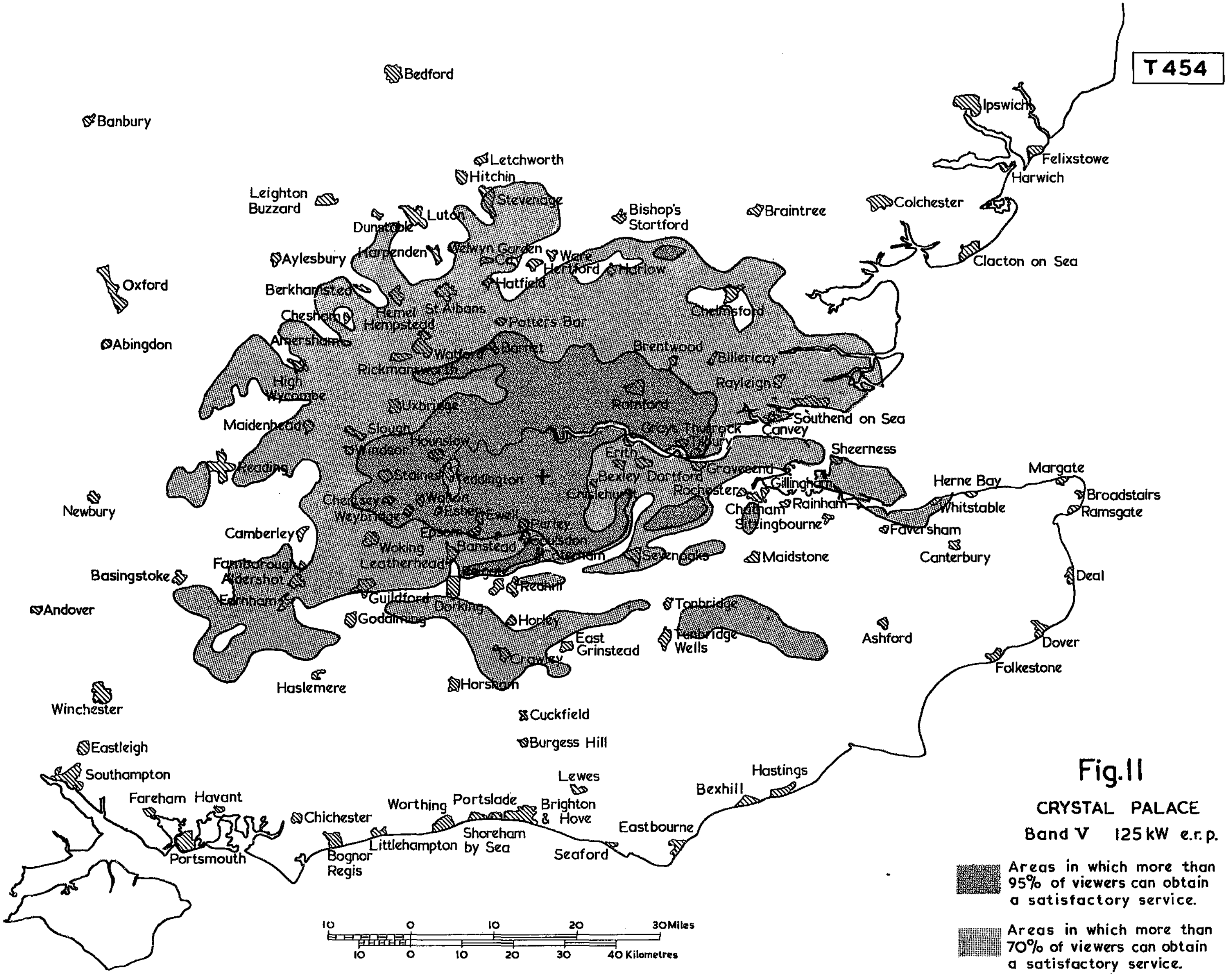


Fig.11

CRYSTAL PALACE

Band V 125 kW e.r.p.

T455

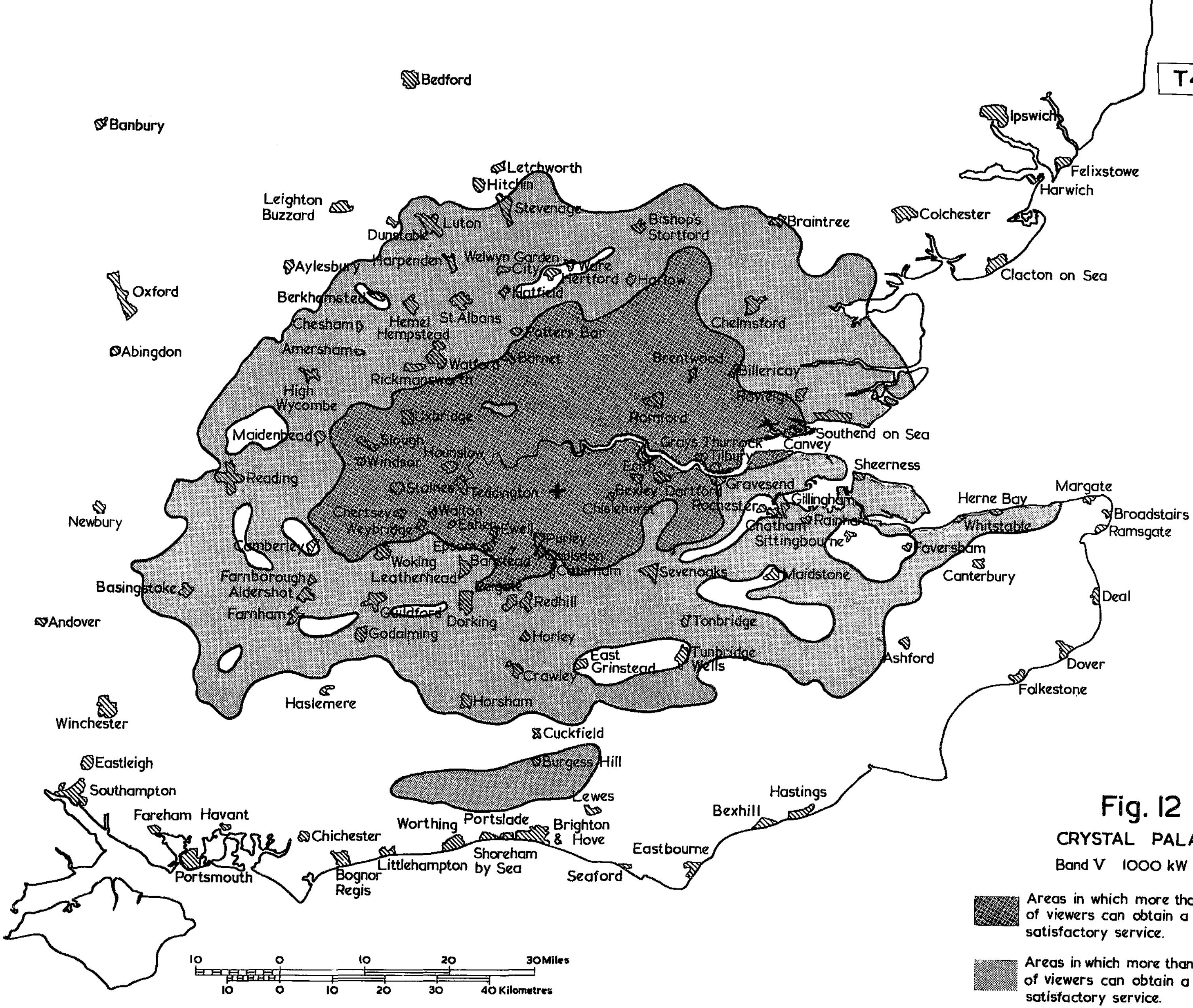


Fig. 12

CRYSTAL PALACE

Band V 1000 kW e.r.p.

▩ Areas in which more than 95% of viewers can obtain a satisfactory service.

▨ Areas in which more than 70% of viewers can obtain a satisfactory service.

T461

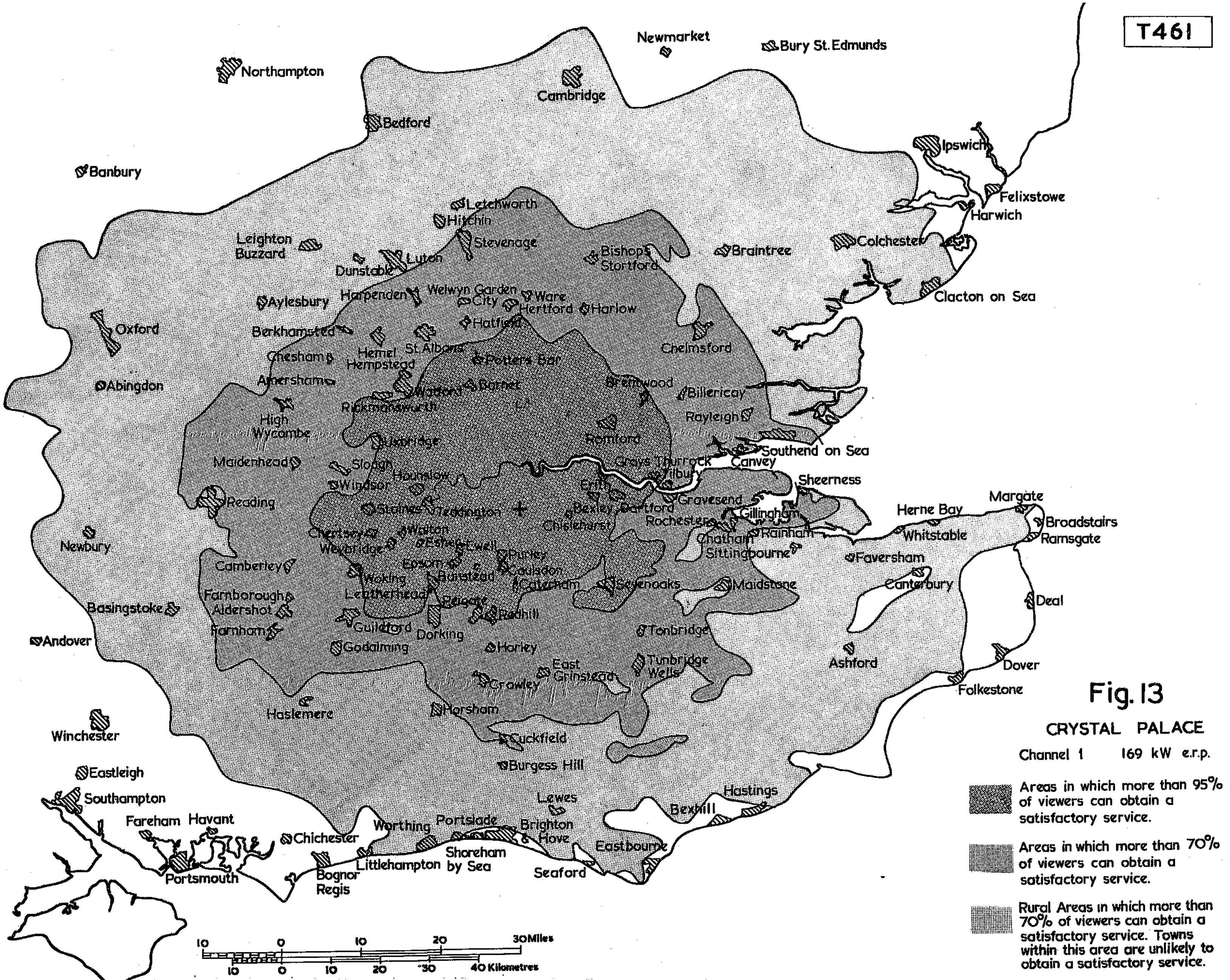


Fig. 13

CRYSTAL PALACE

Channel 1 169 kW e.r.p.

▨ Areas in which more than 95% of viewers can obtain a satisfactory service.

▨ Areas in which more than 70% of viewers can obtain a satisfactory service.

▨ Rural Areas in which more than 70% of viewers can obtain a satisfactory service. Towns within this area are unlikely to obtain a satisfactory service.

Some 600 measurements were made in the Central London area, bounded by Harrow and Tottenham in the north, and by Bromley and Kingston-on-Thames in the south. This does not, of course, provide anything like the information required for a large-scale map of the area, and no attempt has been made to produce one. The size of the buildings in the centre of this area caused wide variations in the measurements, due to dense local shadows, and any distinction between terrain and local obstructions was impossible. At any rate, the statement of field strength at 30 ft (9·1 m) above ground level is not significant when applied to such an area. A major difficulty encountered was due to a gap in the vertical radiation pattern of the transmitting aerial. This affected areas within 14 miles (22 km) of the transmitter, and any corrections for this involved a laborious process. The outer London suburbs which contain the majority of the population were more thoroughly surveyed. In this area the houses are mostly of two storeys.

At ranges for which the effects of tropospheric fading are apparent, it has not been possible to establish sufficiently accurate median values for the field strengths observed. This has been made evident by long- or short-term fading which has caused disagreement in results measured over successive days. It has meant that field strength contours for less than 50 dB have not been shown in Fig. 6, and consequently the 50 dB contour cannot be accurately included in Fig. 7. Fading usually became apparent at distances in excess of 30 miles (48 km) from the transmitter; it was not noticed in pockets of low field strength at short ranges.

4.2. List of Towns Surveyed

The Appendix shows towns which have populations in excess of 10,000 (1951 census). Field strengths available to 10%, 50% and 90% of their inhabitants are given, together with the values provided by the present Band I service from Crystal Palace.

Some idea of the degree of signal variation is given by the variation factor (the 50%/90% value). This is more properly the town variation factor, as distinct from the local variation factor, which may be defined as the 50%/90% value for an area of one square kilometre, given that there are no fundamental topographical changes over this area, and that the transmission path is not materially affected by travelling within the confines of the square kilometre. Thus it will be seen that the local variation factor is a measure of the variation caused by local obstacles, whereas the town variation factor will include local obstruction losses, topographical changes and transmission path variations since measurement is made over the substantially larger town area. Fig. 14 is a graph showing how the factors in built-up areas vary. The greater spread of the town curve is due to the larger areas of the towns affected by topographical and transmission path changes as mentioned. Conversely, the smaller areas covered by the villages are not generally affected by such changes. In 4% of cases, the village was situated on the edge of an escarpment, and the variation factor was consequently very large. The village variation factors are approximately equal to those determined from town measurements made in areas of two-storeyed houses. Fig. 15 shows the curves obtained from similar Band I measurements in the Crystal Palace service area.

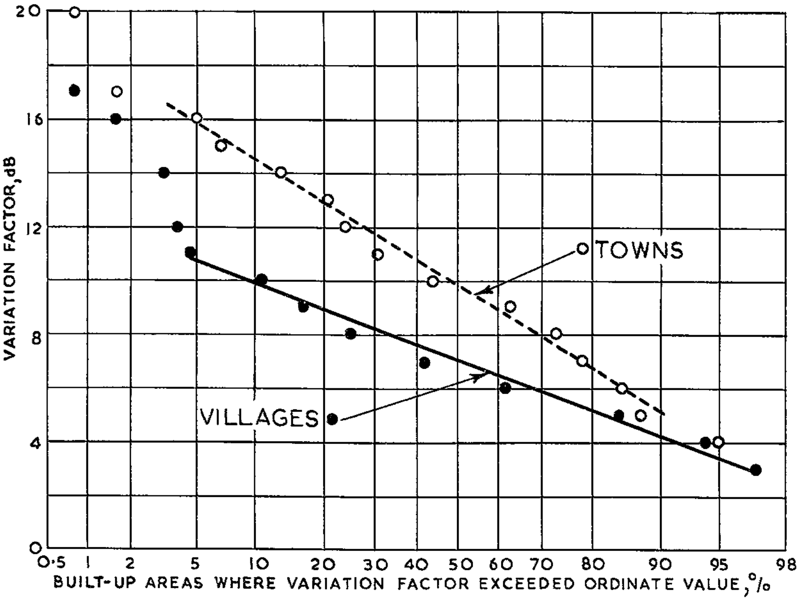


Fig. 14 - Crystal Palace Band V variation factors derived from measurements in 121 towns and 128 villages

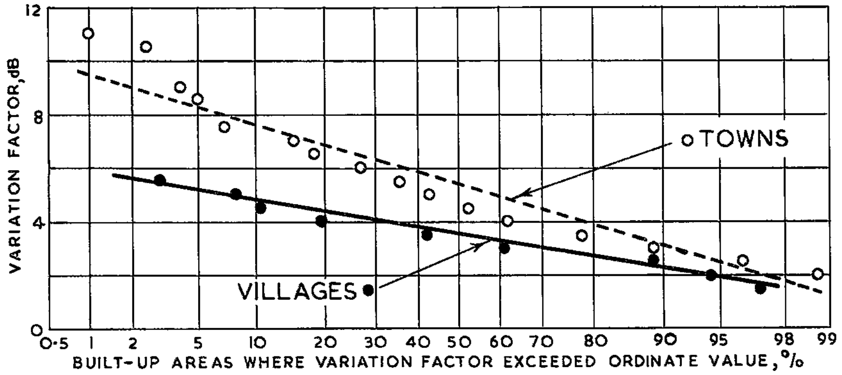


Fig. 15 - Crystal Palace Band I variation factors derived from measurements in 79 towns and 39 villages

Fig. 16 shows the result of plotting median values obtained from town measurements on Band V against distance from the transmitter. A best-fit curve has been calculated and is shown. Since the sharp vertical radiation pattern of the transmitter aerial affected areas at close distances, median measurements up to 14 miles (22 km) have been limited to those for which an approximate correction has been applied. Figs. 17 and 18 show similar curves plotted for Bands I and IV, respectively. The three curves have been drawn for an e.r.p. of 125 kW, but it should be recalled that, whereas the Bands I and IV transmitting arrays are about the same height above ground, the Band V array is 261 ft (80 m) higher. Study of the curves for Bands I and V will reveal that the increased transmitting aerial height of Band V, extending the optical horizon by nearly 8 miles (12·8 km), has decreased the gradient of the curve and extended the range, both curves crossing the optical horizon

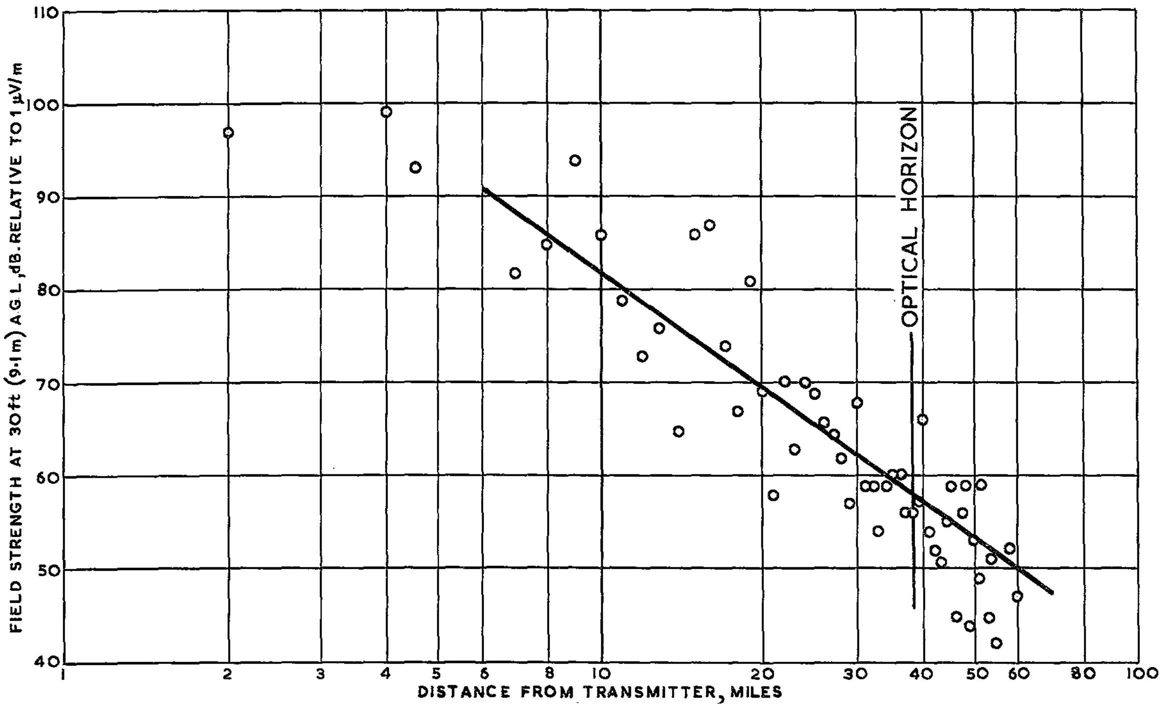


Fig. 16 - Crystal Palace Band V - 654 Mc/s

Transmitter aerial 691 ft (210 m) a.g.l.

E.R.P. = 125 kW

Variation of field strength with distance derived from spot measurements in towns

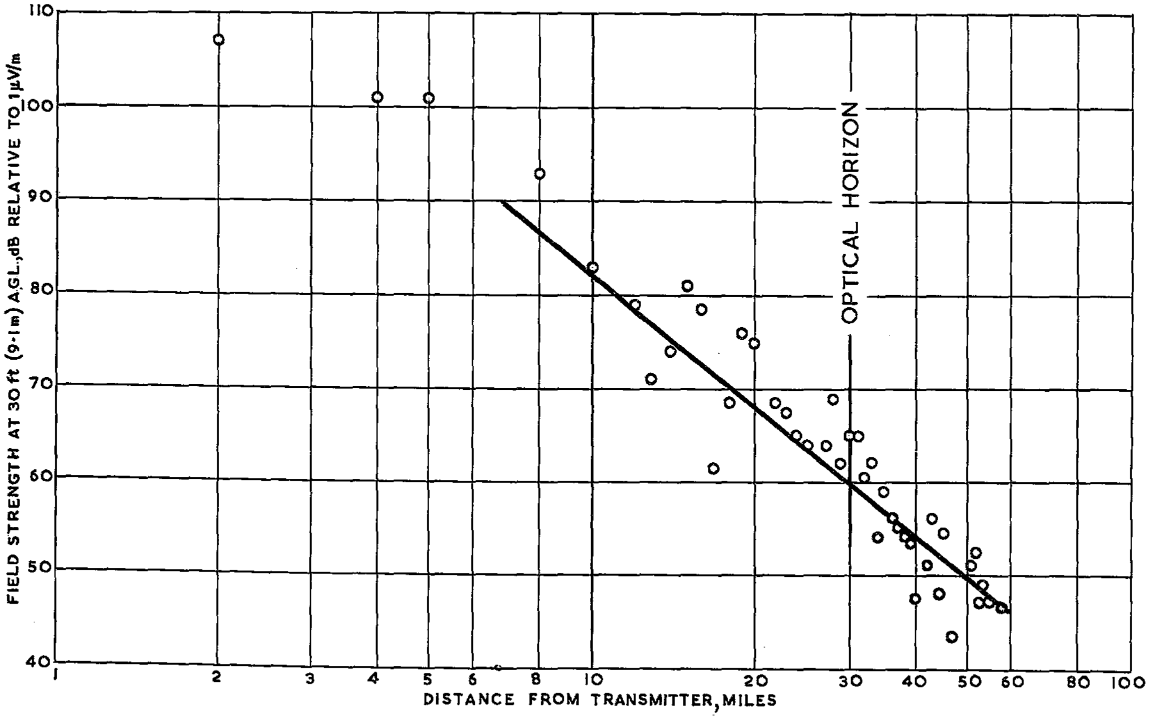


Fig. 17 - Crystal Palace Band I - 45 Mc/s

Transmitter aerial 426 ft (130 m) a.g.l.

E.R.P. = 125 kW

Variation of field strength with distance derived from continuous measurements in towns

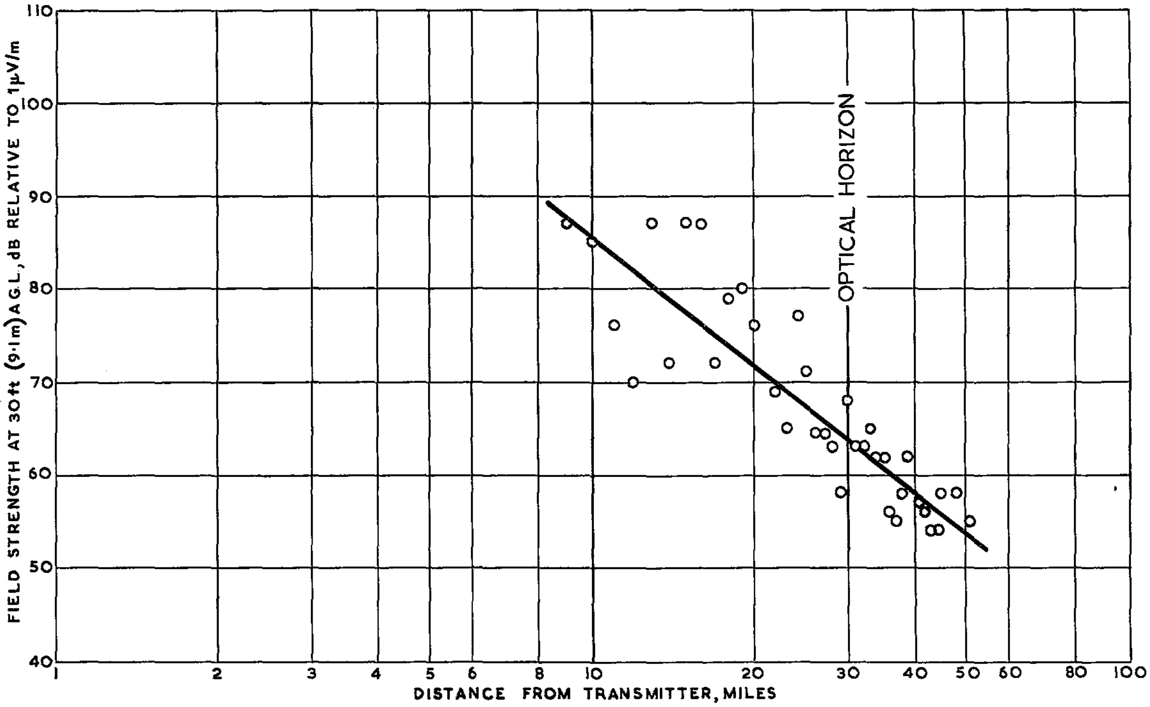


Fig. 18 - Crystal Palace Band IV - 495 Mc/s
Transmitter aerial 430 ft (131 m) a.g.l.
E.R.P. = 125 kW
Variation of field strength with distance derived from continuous measurements in towns

at approximately the same field strength. The curve showing the Band IV result has a gradient which approximates to the Band I value, as may be expected from the nearly equal aerial heights. It is also displaced throughout by about +3·5 dB; this may possibly be attributed to the use of an omnidirectional receiving aerial, as discussed earlier, and to the method of analysis used on Band IV. The frequency gain which could be expected on Band V has been nullified by the effect of terrain.

4.3. Other Results

It has already been mentioned that the results obtained by the B.B.C. field-strength unit were used to obtain the results in this report. Where possible these values have been checked and data added from supplementary information supplied by other organizations. Because of the different techniques used exact comparison proved difficult, the major cause of discrepancies being the choice and distribution of the sites measured.

A common effect frequently observed throughout the tests was the fluctuation of field strength while the receiving aerial was static. The worst examples were found when the aerial was obscured from the transmitter by neighbouring trees. Wind movement of the trees caused random changes of up to 15 dB, and even on comparatively calm days the slight motion caused 6 dB fluctuations at some of the worst sites. Wind movement of the receiving aerial seldom caused much fluctuation, although some attenuation was noticed in heavy rain. Motion of the surface at the ground reflection point caused signal variation, and on one occasion a flutter of 5 dB was traced to the movement of tree-tops at the reflection point, although the transmitter aerial was in full view of the receiver. Passing traffic caused fluctuations of signal when measurements were being made in busy thoroughfares, although it was observed that this effect decreased as the receiving aerial height increased. For measurement purposes no attempt was made to improve upon the receiving conditions at a selected measuring point by finding the most favourable aerial position. In supplementary tests, however, the optimum position was found to be extremely critical. This confirmed the experience gained on house measurements on Band IV. Thus the dense shadow which exists, in the u.h.f. band, on the side of a building away from the transmitter would prohibit the siting of an array on this side. Indifferent location on the side towards the transmitter may produce poor results and it was often possible to obtain considerable improvement by very slight adjustment in the aerial position. Nearby obstacles must be taken into account, and trees in the direction of the transmitter are, as has just been stated, often particularly troublesome.

Apart from the effects on the measured amplitude of the received signal determined by the use of an omnidirectional receiving aerial, multipath distortion has not been studied by the B.B.C. field-strength unit. During the Band IV tests the transmitter was operated on pulse modulation for a time, and the delays and amplitudes of echoes were measured at many sites. It was felt that multipath distortion could prove serious, but the use of highly directive aerials by the picture assessment teams revealed very little trouble during the Band V tests. However, the quality of the picture is very dependent on the efficiency of the receiving aerial system and location, and it is clear that many of the problems of setting up Band V aerials for would-be viewers will require individual and expert attention.

It was not possible during these tests to observe the effect of aircraft flutter upon a static recording since the response times of the receiver and recorder metering circuits were too slow.

In general, the wide differences in the results of the various phases of the survey have illustrated the need for extreme caution in the assessment and statement of results.

5. CONCLUSIONS

A Band V transmitter of 1000 kW sited at Crystal Palace would provide a satisfactory service to the majority of the population of south-east England. It may be that a better service could be provided by one transmitter of moderate power and several translators, since the shadows cast by one point source of high power could be more numerous than those due to several low-power sources suitably sited. In areas which are hillier than the Home Counties the problem would become more severe, although the ability to produce high-gain transmitting and highly-directional receiving aerials would resolve some of the difficulties. Such receiving aerials are expected to overcome most of the troubles associated with multipath distortion, but the need for care in the house installation cannot be too strongly emphasized.

The use of u.h.f. would accentuate the need for an acceptable method of measurement, and while the results obtained at an aerial height of 30 ft (9·1 m) above ground level have been used for this report, the possibilities of improvement in the technique cannot be excluded. The question of how to present the result of a survey is important, for while the ordinary contour map gives a good idea of the service area it possesses certain limitations, especially noticeable at the higher frequencies and in difficult terrain. It is likely that maps based upon field strength measurements and subjective assessment and showing the percentage of viewers who could expect to receive a satisfactory service, would be more easily interpreted by users who are not professional engineers or physicists.

6. REFERENCES

1. TAC/TSC/CP.188/58.
2. "Final Report on Crystal Palace Band IV Survey", Research Department Report No. K-127/2, Serial No. 1958/14.
3. Whittaker, E. and Robinson, G., "The Calculus of Observations", (Blackie and Son, Ltd., 1924), pp. 197-199.

APPENDIX

Town	BAND V Field strength at 30 ft (9·1 m) AGL 691 ft (210 m) aerial 125 kW e.r.p. dB relative to 1 μV/m			BAND I Field strength at 30 ft (9·1 m) AGL 426 ft (130 m) aerial 169 kW e.r.p. dB relative to 1 μV/m		
	10%	50%	90%	10%	50%	90%
Abingdon	49·0	42·0	35·0	51·0	48·0	44·5
Aldershot	83·5	74·0	64·0	73·5	69·0	64·0
Amersham	78·0	71·0	63·0	74·5	71·0	65·0
Aylesbury	57·5	48·0	39·0	56·0	53·0	50·0
Barking	96·5	94·5	91·5			
Barnet	95·0	87·0	78·0			
Basingstoke	65·5	56·5	48·0	60·0	55·5	50·0
Berkhamsted	62·0	53·0	44·0	68·0	61·5	57·0
Bexley	91·5	81·5	71·5			
Billericay	88·0	80·0	72·0			
Bishop's Stortford	72·0	62·0	52·0	67·5	61·0	54·5
Braintree	70·5	57·5	44·5	57·5	53·0	47·0
Brentwood	91·0	81·0	72·0			
Camberley	57·0	52·0	46·0	68·0	64·0	60·5
Canvey	86·0	83·0	80·0			
Caterham	83·0	75·0	67·0	92·0	84·0	74·0
Chatham	64·0	48·0	34·0	68·0	60·0	47·0
Chelmsford	71·0	59·0	45·0	65·0	61·0	57·0
Chertsey	90·5	86·5	82·5	80·0	78·0	75·5
Chesham	73·0	63·0	54·0	70·0	62·0	53·0
Chislehurst	93·0	82·0	70·0			
Clacton-on-Sea	51·0	46·0	40·0	50·0	47·5	44·5
Colchester	58·0	39·0	–	53·0	48·0	42·5
Crawley	76·0	74·0	71·0	74·0	70·5	67·0
Croydon (North)	105·0	97·0	87·0			
(South-east)	103·0	93·0	82·0			
(South-west)	108·0	99·0	90·0			
Cuckfield	68·0	55·0	40·0	70·0	62·5	56·5
Dartford	99·5	86·5	73·5	86·0	82·0	76·5
Dorking	72·5	60·0	47·5	66·5	62·5	55·5
Dunstable	63·0	52·0	40·0	57·5	54·5	51·5
East Grinstead	67·0	57·0	41·0	79·0	73·5	65·5
East Ham	95·5	92·5	89·5			
Epsom and Ewell	102·5	94·5	87·5			
Erith	75·0	65·0	55·0			
Farnborough (Hants)	73·0	63·5	54·5	70·5	67·0	63·5
Farnham	80·0	73·0	65·0	65·0	61·5	57·5

Town	10%	50%	90%	10%	50%	90%
Faversham	55·0	47·0	39·0	52·5	48·0	44·0
Gillingham	70·5	58·5	45·5	72·0	65·0	60·0
Godalming	73·5	62·0	50·5	66·5	61·0	55·0
Gravesend (East)	80·5	69·5	58·5	76·5	72·0	67·5
(West)	84·0	78·0	71·0			
Grays Thurrock	94·5	86·5	78·5	80·5	78·0	74·0
Guildford	97·0	77·0	57·0	76·0	70·0	63·0
Harlow	74·0	64·0	55·0			
Harpenden	72·0	61·0	50·0	69·0	63·5	58·0
Haslemere	69·5	55·0	41·5	64·5	57·5	52·0
Hatfield	75·0	66·5	58·0	72·0	68·5	63·0
Hemel Hempstead	81·0	67·5	54·0	75·0	68·5	62·0
Herne Bay	71·0	62·0	53·0	58·0	52·0	48·0
Hertford	62·0	53·0	43·0	70·5	63·5	56·5
High Wycombe	84·0	66·0	47·0	71·5	64·0	56·0
Hitchin	55·0	46·0	37·0	57·0	52·0	48·0
Horley	71·0	62·0	51·0	74·0	69·5	67·0
Horsham	69·0	58·0	49·0	60·0	56·5	52·5
Ilford	94·5	91·5	88·5			
Leatherhead	86·0	74·0	63·0	78·5	75·0	71·5
Leighton Buzzard	61·0	51·0	41·0	55·5	51·5	48·5
Letchworth	57·0	49·0	40·0	58·0	54·0	50·0
Lewes	66·0	51·0	37·0	62·5	51·0	39·5
Luton	78·0	63·0	47·0	63·5	57·0	51·0
Maidenhead	86·0	76·0	66·0	72·5	67·5	64·5
Maidstone (North)	65·5	53·5	40·5	66·0	58·0	48·5
(South)	69·5	55·5	41·5			
Newbury	57·5	51·0	44·5	53·0	50·0	46·0
Potters Bar	85·5	76·0	67·0			
Purley and Coulsdon	102·0	85·0	69·0	100·5	94·0	83·0
Rainham (Kent)	69·0	61·0	53·0			
Rayleigh	78·0	73·0	68·0	71·0	66·0	61·5
Reading	70·5	61·5	52·5	64·0	59·5	54·5
Redhill	73·0	60·0	45·0	84·5	77·0	69·5
Reigate	68·0	58·0	48·0	77·5	72·0	65·0
Rickmansworth	72·0	69·0	65·0	78·5	74·0	68·5
Rochester	70·0	55·0	38·0	65·5	60·0	55·5
Romford (North)	92·5	88·5	84·5			
(South)	96·0	91·0	85·0			
St. Albans	82·0	72·0	61·0	72·5	69·0	63·0
Sevenoaks	75·0	69·0	61·5	84·0	78·5	71·5

Town	10%	50%	90%	10%	50%	90%
Sheerness	76·5	70·5	64·5	64·0	59·5	56·0
Sittingbourne	61·0	51·0	40·0	57·0	52·5	48·0
Slough	90·5	83·5	76·5	74·5	70·5	68·0
Southend (East)	77·5	68·5	59·5	67·5	61·5	55·5
(West)	81·0	66·0	53·0			
Stevenage	76·0	69·0	62·0	66·0	62·0	59·0
Teddington	89·0	83·0	78·0			
Tilbury	93·5	87·5	82·5	77·5	72·5	69.0
Tonbridge	70·0	60·5	51·0	69·5	63·5	57·5
Tunbridge Wells	70·0	55·5	41·5	66·0	60·5	53·0
Uxbridge	95·0	83·0	71·0			
Walton and Weybridge	96·5	88·5	78·5	83·5	79·5	76·0
Watford	79·0	70·0	61·0	76·0	72·0	67·5
Welwyn Garden City	79·0	70·0	60·0	72·0	68·5	64·0
Whitstable	70·0	64·0	58·0			
Windsor	85·0	77·0	68·0	73·0	68·5	61·5
Woking	85·0	74·0	63·5	75·5	71·5	67·0

EGF